



TITULO

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The GTC Project. Present and Future

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ABSTRACT

The GTC (Gran Telescopio Canarias) Project, a 10 meter segmented telescope to be installed at the ORM in La Palma, Spain, is moving forward at full steam. Main science drivers for the GTC are image quality, operational efficiency and reliability. First light is planned for end-2002.

The GTC Project, initiated in 1996, is progressing well on schedule and budget and its construction has started in October 1999 with groundbreaking. All major contracts have by now been awarded. Three science instruments have been approved for phase A studies, representing a wavelength coverage from the optical-UV to the mid infrared, in imaging, and multi-object low resolution spectroscopy. P.I. teams from Spain, France, Mexico, the U.K, and the USA are participating in the preliminary design of the Instruments. The future operation and maintenance of the GTC is being studied and discussed within the PO and the astronomical community.

The GTC Project Board has recently approved plans for after Day One. These include the development of new instruments and upgrades for the GTC plus an Adaptive Optics Program.

The current status of the project and immediate plans are presented here.

Keywords: Telescopes.

1. INTRODUCTION

The GTC Project is a Spanish initiative lead by the IAC (Instituto de Astrofísica de Canarias), to build a 10.4 meters segmented telescope at the ORM (Observatorio del Roque de los Muchachos), in the Island of La Palma (see Fig. 1). The GTC Project was approved early in 1996 and is fully funded by the Central Government of Spain (through the Oficina de Ciencia y Tecnología, OCYT) and the Regional Government of the Canary Islands (through the local Ministry of Education, Culture and Sports).

The Conceptual Design of the project was finished during the second half of 1997¹. At that time, the GTC first Light was planned for end of 2002, with scientific operations (Day One) starting by the end of 2003. The estimated cost of the project was 93.5 MUSD (May 1997) where a 10% contingency is included.

Major project contracts have been awarded along 1999. During year 2000 the remaining contracts are being opened for bidding and will be awarded. By now, nearly 2/3 of the originally estimated budget has been committed, the project remaining well within the 1997 estimates. Timewise, the aggressive project milestones that were established in 1997 is nearly secured to be met.

The GTC Project Board, advised by the GTC SAC (Scientific Advisory Committee), has recently approved funds for initiating the Continuous Development Program for the development of new instruments and telescope upgrades after Day One. This program, that will be a key element along the GTC lifetime, will ensure that a continuous flow of new science instruments will be coming to the GTC after Day One to maintain it at the forefront of science. Additionally, an Adaptive Optics Program has been funded to provide AO capabilities to the GTC no later than 2005.

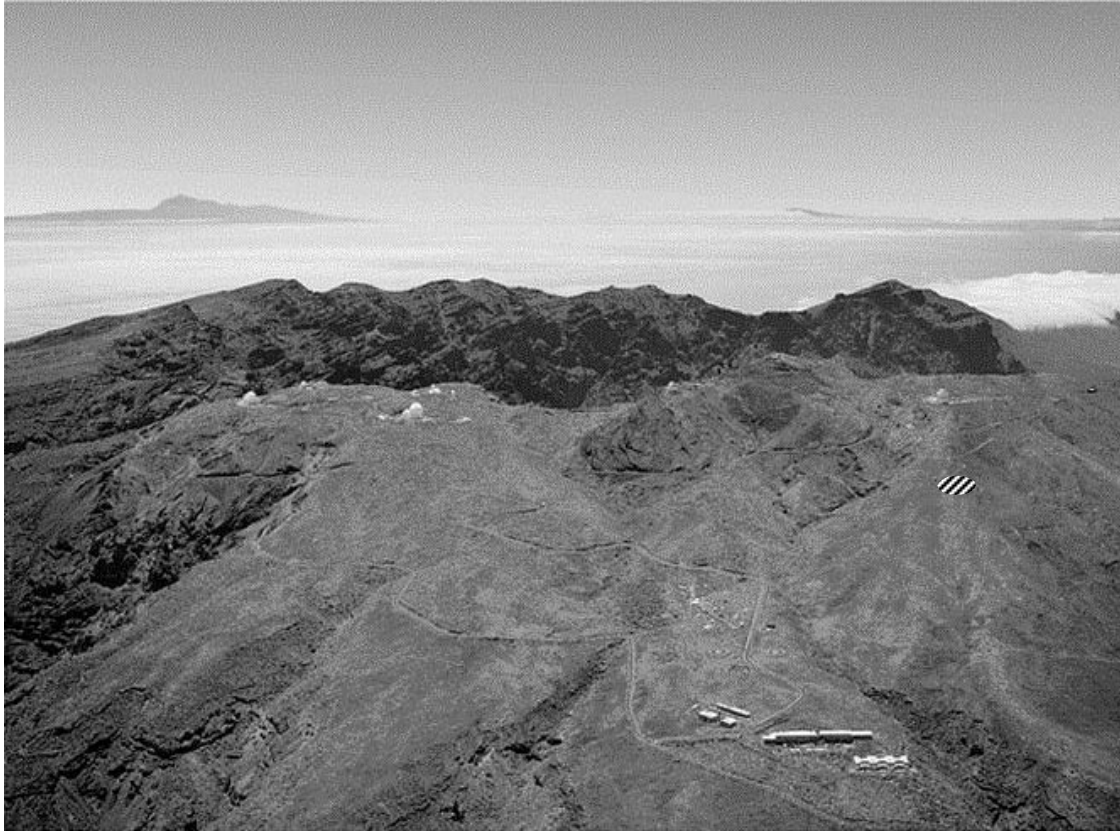


Figure 1.- ORM aerial view. The ORM site is marked with a striped ellipse.

The GTC is taking steps to achieve its main science objectives, namely excellent image quality, high operational efficiency and reliability², both on time and budget. Moreover, the GTC is also set to achieve its full capabilities in the shortest possible time after Day One.

2. PROJECT STATUS

One of the major project milestones reached is the start of the work at site in mid October'99. This work was initiated by ACS, one of the major Spanish Civil Work companies, who was awarded the GTC Civil Work and Auxiliary Equipment contract in September'99. As of now site activities include earth moving for site preparation and the access road to this site from the current observatory road. Shortly the foundations for the telescope pier will be initiated. The progress of this work can be monitored through a live web camera available in the project web pages (www.gtc.iac.es). Fig. 2 shows a view of this site work.

The GTC Civil Work will continue until the end of 2001 but the concrete part of the telescope enclosure will be finished at the end of 2000 to be ready to support the GTC Dome that will be brought to site along the year 2001.

The GTC enclosure and auxiliary buildings will be situated at an altitude of 2267 meters in the ORM. They will occupy a surface of about 2400 square meters over a ground platform of 5000 square meters. Three different areas will be built, namely, the telescope enclosure, an annex building, where the telescope control room, direct services for the telescope and some office space will be housed, and an auxiliary building, well separated from the telescope area, where the major heat load producing equipment will be situated together with the warm air exhaust.

The GTC Dome is being built by the joint enterprise UTE GMU formed by GHESA, a solid engineering Spanish (Madrid) company, MONCAINSA, an experienced Spanish (Gran Canaria) site installation company, and URSSA, a first class Spanish (Alava) steel manufacturer. They were awarded this contract at the end of July'99. The detailed design will finish



Figure 2.- Web camera view of the work performed at GTC site until the 22/02/00

in February'00 and the dome construction will start then. The Dome will be tested at the factory at the end of the year 2000 to reduce the risk during the final assembly at site where it will be erected along the year 2001. Two rows of windows situated around the GTC Dome and an additional row of windows situated around the concrete Dome base will provide a total of 228 square meters of open surface to facilitate the natural ventilation of the telescope enclosure³. A forced ventilation system will be available for ventilating the telescope chamber when the natural ventilation is not sufficient. Fig 3 shows the current GTC Dome and Building design.

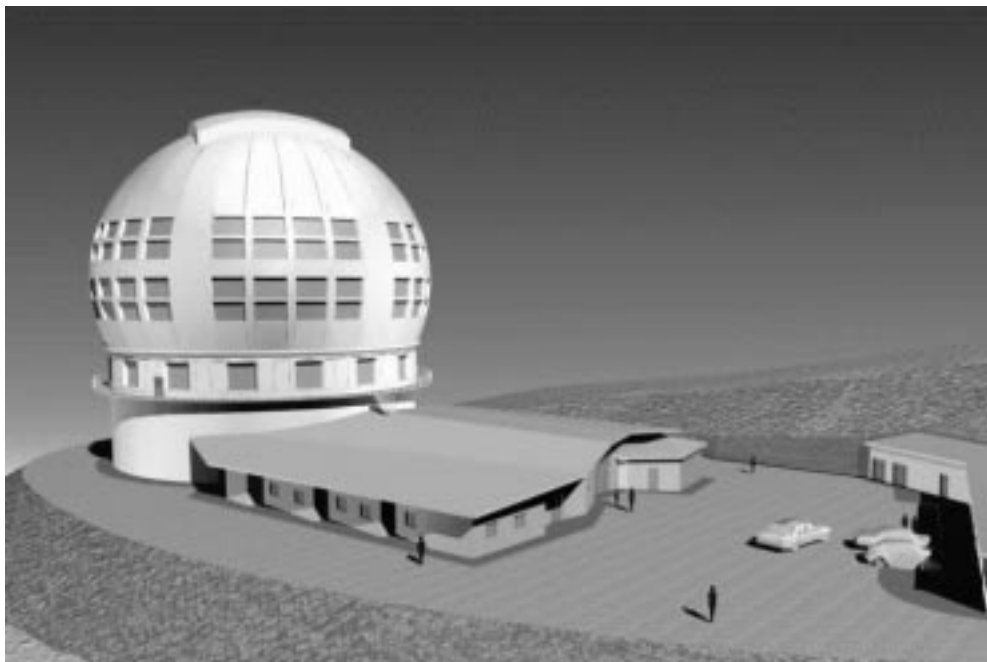


Figure 3.- Artistic view of the GTC buildings and dome.

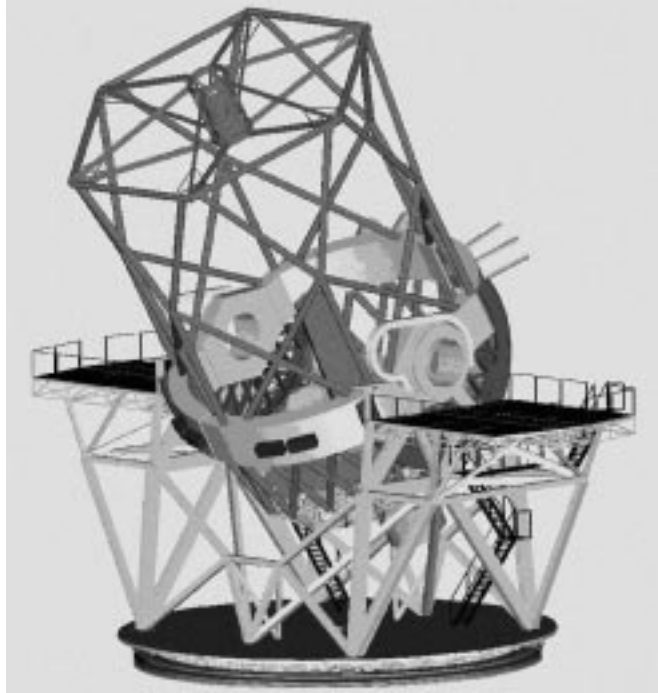


Figure 4.- 3D image of the GTC telescope.

The GTC Telescope Mechanics was awarded in November'99 to the joint enterprise UTE SG formed by GHESA and SCHWARTZ-HAUTMONT, a well known Spanish (Tarragona) structural fabricator. The fabrication will be initiated in September'00, after the end of the detailed design. Factory test will be initiated in August'01 and the erection in the ORM is planned for the first half of the year 2002. The high stiffness of the GTC Telescope will be achieved after a carefully modeling and design and the use of hydrostatic bearings, direct motor drives and optical encoders^{4,5}. Fig 4 show a 3D view of the GTC Telescope structure.

The material selected for the blanks of the primary mirror segments is ZERODUR™ from SCHOTT (Mainz, Germany).



Figure 5.- Official reception of the first GTC segment blank at SCHOTT factory.

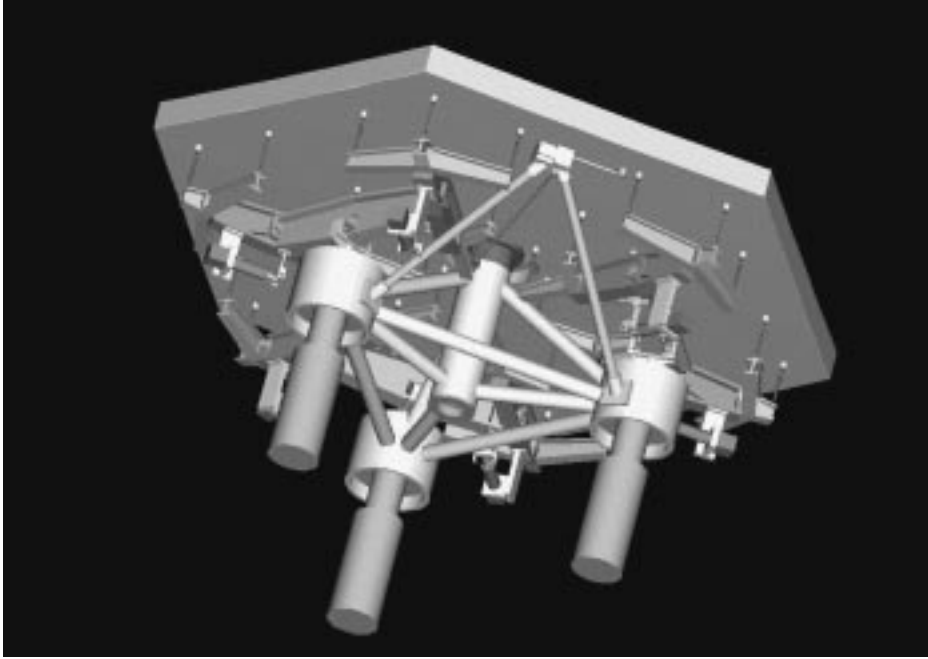


Figure 6.- 3D image of the GTC segment support system.

This selection has been based on the high homogeneity of CTE. A characteristic needed due to the high demanding requirements of GTC for image quality. SCHOTT was awarded with a contract to supply the 42 GTC segment blanks in February'99. The first two blanks were provided at the end of January'00 (see Fig 5) and this supply will continue smoothly along the years 2000 and 2001.

The polishing and testing of these segment blanks will be performed by REOSC (Paris, France). REOSC was awarded with a contract to perform the polishing and testing of the primary mirror segments in January'00 due to his high experience in this type of work for large telescopes, the proved ability to achieve the GTC requirements and the redundancy and robustness of the testing procedure. First segments will be delivered in February'02 and they will continue up to the end of the year 2003, when the last segments (the spare ones) will be delivered. First light of the GTC, planed for end 2002, will be done with 12 to 18 segments installed⁶.

The primary mirror support system has been splited in two parts: the passive one (see Fig. 6), formed by the whiffletrees, the force actuators for correcting the segment shape, the central support and the segment sub-cell; and the active one, formed by the segment actuators and the edge sensors. The passive support system has been awarded to CESA, a Spanish (Madrid) aeronautical company, in January'00. They where selected due its high experience and quality doing complex and high demanding and reliability mechanisms. These systems will be integrated with the segments at the REOSC factory for final polishing and testing.

The construction of the Acquisition, Guiding and Calibration Modules for the two nasmyth GTC foci are in the bidding process and will be awarded along March'00. These modules will perform not only the more standard functions of telescope acquisition and guiding but also the function of primary mirror calibration on tip, tilt and phasing⁷. These modules will be installed at the telescope at the end of the year 2002, just before the GTC First Light.

Other GTC subsystems like the primary mirror segments active support system, the secondary and tertiary mirrors or the coating plant are under specifications and will be awarded along this year 2000.

Three science instruments have been selected to be the first GTC instruments and will cover a wide range of wavelength from the visible to the medium IR with imaging and low resolution capabilities: OSIRIS, EMIR and CANARI-CAM (see Fig. 7). They are extensively described in various papers of this SPIE conference^{8,9,10,11}.

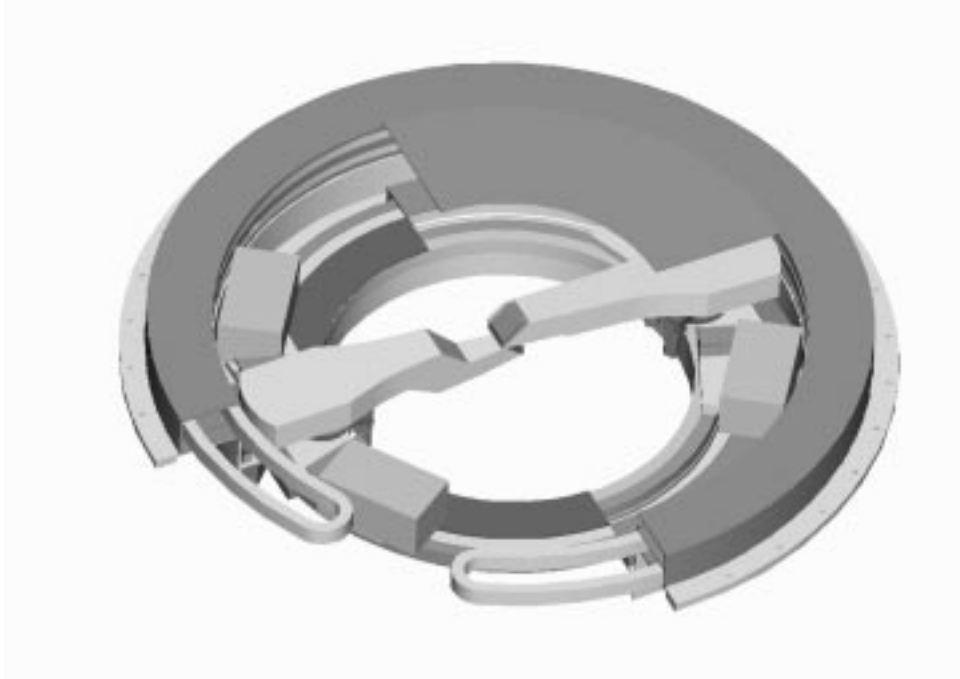


Figure 7.- 3D image of the Acquisition, Guiding and Calibration Module.

The GTC Control System is progressing well. A key System Design Review was held past January'00 and a prototype implementing the selected technologies was developed. It will be extensively based on Object Oriented programming, CORBA and ATM communications^{12,13}

All these major steps done along the year 1999 and the status of the ones planned for 2000 put high confidence on the achievement of the project scope and the GTC scientific requirements on time and in the estimated budget.

3. CURRENT PROSPECT

Foreseen Day One configuration

According to the current plans the GTC will reach first light on December 2002, and be ready for Science Operation in December 2003. At that time the GTC will be provided with two Nasmyth Focal stations supplied with a science instrument each, as well as their corresponding rotator adapters and Acquisition and Guiding boxes. The later will be used on top of their nominal tasks of acquisition and guiding, for calibration of the GTC active optics system. This includes segment figure sensing as well as tip-tilt and image motion correction features. Additionally, seeing monitoring will be also performed by the A&G box⁷.

The entire facility will be managed by an advanced control system that will deal with every single subsystem, including telescope and dome motions, optics behaviour, instruments control and data acquisition and handling^{12,13}.

An operation plan is being prepared contemplating the logistics of scientific operation and maintenance, with a view to include in the GTC design features aimed at achieving a cost-effective operation¹⁴.

Foreseen Capabilities

We expect the GTC to reach the science requirements as dictated by the Scientific Advisory Committee and adopted in the GTC requirements document. In fact, after most of the large contract have been let, no downgrading of the science requirements has been accepted nor required to date. Therefore, the original requirements of image quality and operational efficiency are fully valid. Hence, we do expect the GTC to meet the on-axis image quality figure of 0.18 arc second , or its CIR= 0.74 equivalent.

Regarding operation, the adoption of service flexible observing will be greatly facilitated by the number of focal stations available and the capacity to change from one to another, simply rotating or even parking the tertiary mirror. Algorithms for setting up and managing the various observing queues are being designed, where the efficiency is measured with regards to several quality parameters that consider not only the current weather conditions, but also the level to which a given scientific programme has been advanced to completion, or how to avoid unnecessary instrument or focal station changes.

Two science instruments will be available and commissioned by the time the GTC is handed over to the operation group. A further science instrument is being designed that will be at the GTC one year later^{9,11} (this first second generation instrument will be further mentioned in the following section).

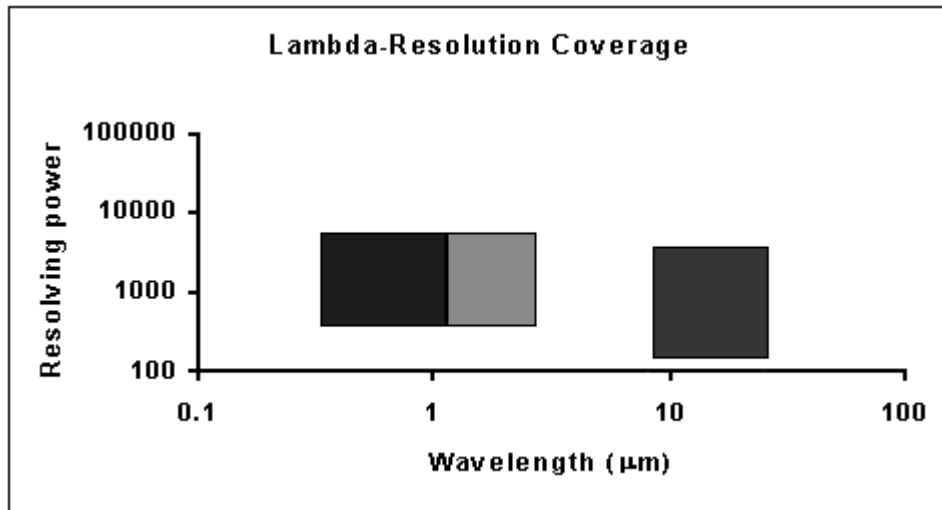


Figure 8. Wavelength-Resolution coverage of the GTC shortly after first light

Relevant (unique) features

Single five-axis controllable secondary mirror catering for optical and IR observations. Specs: Chopping frequencies, fast tip-tilt frequencies, etc. Tertiary mirror can be parked or placed in the beam on real time via software. This allows switching between focal stations to adjust to changing weather conditions⁶.

A&G box includes calibration module for primary mirror segments, as well as for the active optics control of the GTC.

OSIRIS and its tunable filters combined with CCD detectors capable of charge shuffling will be unique for performing narrow band imaging of faint galaxies, or in general of faint extended objects, with on chip background subtraction, and hence much reduced noise.

CANARICAM will offer imaging (with coronagraphy) and spectropolarimetry in the thermal IR bands, allowing the study of heavily reddened objects, like star formation cocoons, or primeval galaxies undergoing episodes of strong star formation. This will be of importance for the determination of the star formation rate of the local and relatively near universe. This instrument combined with the Mexican 50 m sub-millimeter antenna will be unique for detecting primeval galaxies soon after their formation epoch and for identifying their present epoch counterparts.

4. MEDIUM TERM PROSPECTS

Currently Planned Activities

Though the scope of the GTC is limited in time and budget, the Project Board, upon demand from the SAC has authorized the Project Office to start programs whose completion date lies beyond the date in which the P.O. will hand over the GTC

to the operations group. One such program is a third science instrument that should enter operation one year after hand over. A second such program is the Adaptive Optics program that is currently at the conceptual design phase and should be in operation 3 years after first light, i.e. in December 2005. Further on these programs below.

Second-generation instrument

The first second-generation instrument is currently undergoing its preliminary design phase. The instrument consists of a multi-object near IR spectrograph capable of working up to the K band, with a cold mask unit that allows near real time mask changes without warming up the entire instrument. This instrument is meant to determine the star formation rate of the Universe based on H_{α} measurements of galaxies of up to $z=3$.

Adaptive Optics

With the inclusion of Adaptive Optics systems in modern large size telescopes, we gain the combined capabilities of high spatial resolution and very faint sensitivity limits. No medium to large size telescope can be thought of that does not include an Adaptive Optics system. As such, a programme for providing an advanced Adaptive Optics system for the GT has recently been approved by the GTC Project Board. According to this programme, an A. O. system should be available at the telescope by end-2005. The plan that has been established calls for having a conceptual design ready by the end of 2000. Currently we are putting together with the help of the Science community the list of requirements reflecting the interest of Spanish scientists. This will drive the final choice of high order adaptive system for the GTC.

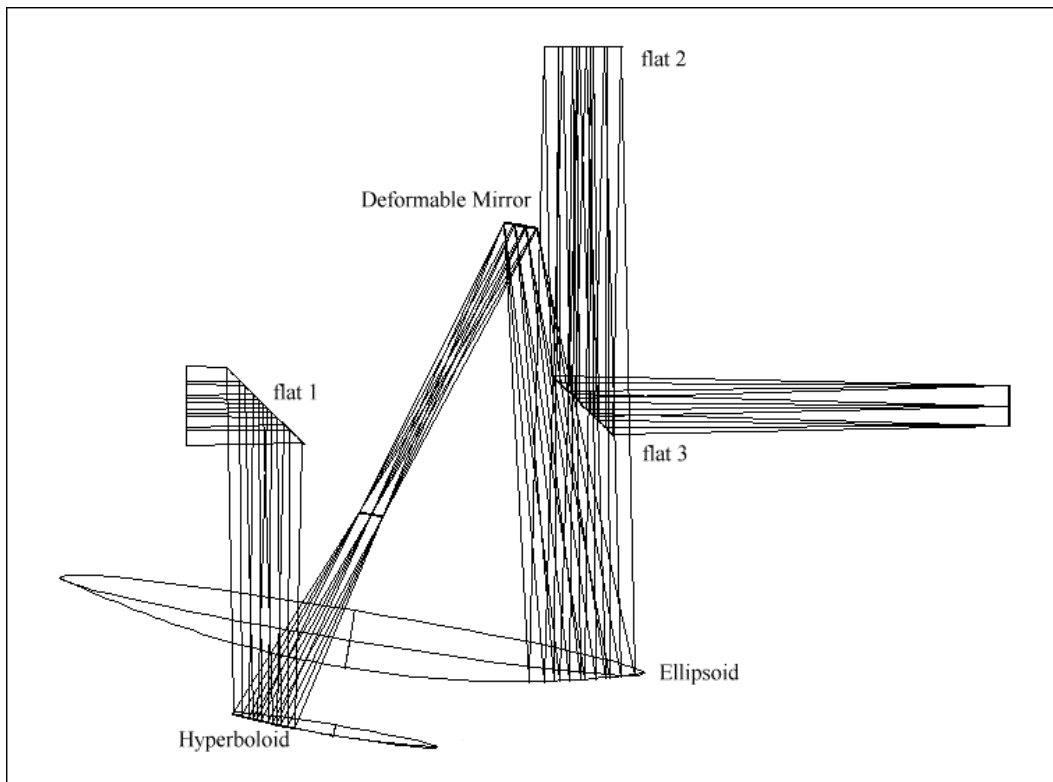


Figure 9. Layout of the optical elements of the Richardson design modified to satisfy the GTC AO requirements.

A straw-man design had been previously made by the P.O. (see Fig. 9) in order to demonstrate the feasibility of an adaptive optics system that could be accommodated in one of the Nasmyth trunnions. This basic design allows for an “fixed-focus” A.O. system that can be inserted or removed from the beam without changing neither the focal plane position, the focal ratio of the incoming beam, nor the exit pupil distance to the image plane. The left over reduction in Strehl ratio is under 2% at $2.2 \mu\text{m}$ over a 2 minutes field of view in a curved image plane (see Fig. 10).

A science instrument for exploiting the capabilities offered by the Adaptive Optics system is included in the development plan. It is therefore foreseen to issue a call for proposal for an adaptive optics instrument in 2001.

Future Development Programme

The two instruments mentioned above, complemented with the first second generation instrument, would provide a very useful combination of instruments allowing many interesting projects to be carried out successfully soon after the GTC enters operation. Besides, the addition of the Adaptive Optics program will add high spatial resolution capabilities. However, while this suit of instruments can make the GTC one of the most sensitive telescopes in the world the lack of high spectral resolution capabilities is readily apparent (see e.g. Fig. 8). It is also of utmost importance to make sure that the development of the GTC continues well beyond Day One.

Since its initial planning the GTC project underscored the importance of a future development program that would be crucial for maintaining the GTC at the forefront of scientific research. The SAC has discussed this development program and has recommended the establishment of a calendar for future developments along the following lines:

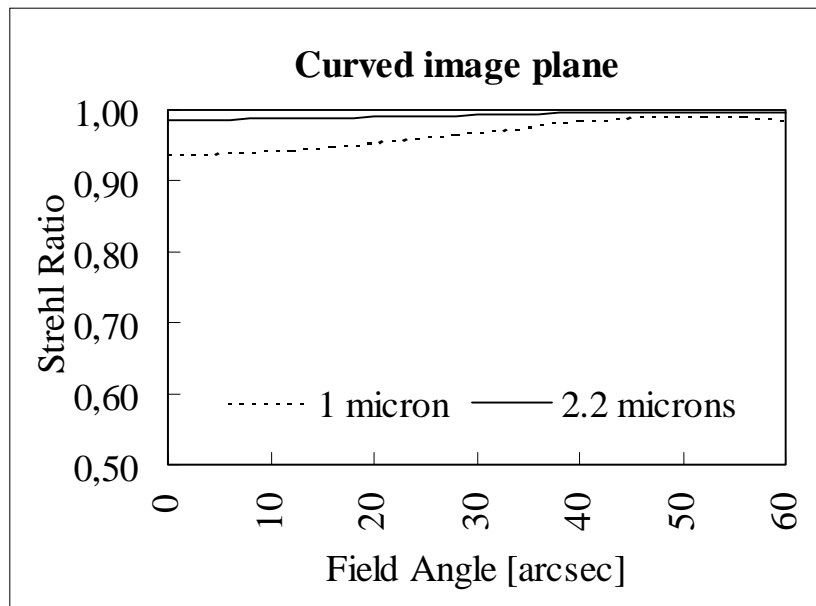


Figure 10. Strehl ratio at 1 μ m (dashed) and 2.2 μ m (solid) as a function of field position on an image plane with radius of curvature 1718.6 mm.

The Cassegrain and Bent Cassegrain foci

Currently the GTC scope includes two operational foci at Day 1, namely the two Nasmyth foci, the remaining foci are to be funded from future development funds made available to the GTC. It is clear that additional foci need to be commissioned before additional instruments can be brought to the GTC. It is therefore obvious that the next focus that should be brought on line is the Cassegrain Focus as it enjoys one less reflection.

There will be significant pressure, particularly from the thermal IR instruments, to put the Cassegrain focus into operation. Also, instruments performing polarimetric observations will prefer to be sited at the Cassegrain focus. Last, but not least, the implementation of queue scheduling will benefit greatly from the availability of several instruments in different focal stations ready to begin operation as needed. Therefore, the Cassegrain focus package, including a rotator-adapter and acquisition and Guiding box, should be on line at the telescope by mid 2004, when the first second-generation instrument is brought to the telescope.

In addition to the Cassegrain focus, a Bent Cassegrain focus will be needed to free one of the Nasmyth platforms for the Adaptive Optics system. This Bent Cassegrain focus will be equipped with both a rotator-adapter and Acquisition and Guide box.

The high resolution spectrograph

If the above plan goes as pictured it is clear that the community will urgently demand high-resolution spectroscopic capabilities. This is an area where large telescopes also show clear advantages. It is therefore envisaged that an announcement of opportunity geared toward procuring a high resolution optical spectrograph for the GTC should be issued in 2002. This high spectral resolution instrument should be brought to the Telescope in late 2006.

The laser guide star

Soon after the Adaptive Optics system is commissioned at the telescope, the demands for observing at any position in the sky will increase and a Laser Guide Reference Star will be required. The GTC will benefit from the wide body of expertise that will have been accumulated by that time in relation with laser guide-star production technologies. A programme aimed at producing a laser guide-star system for the GTC will therefore be started in 2002. An important task of this programme will be to make a choice of the type of system to be employed by the GTC. Hopefully, that system will have already been developed to the extent that the Project Office will not need to make additional developments to that respect.

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